Hydropower Engineering

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MSC.HYDROPOWER ENGINEERING

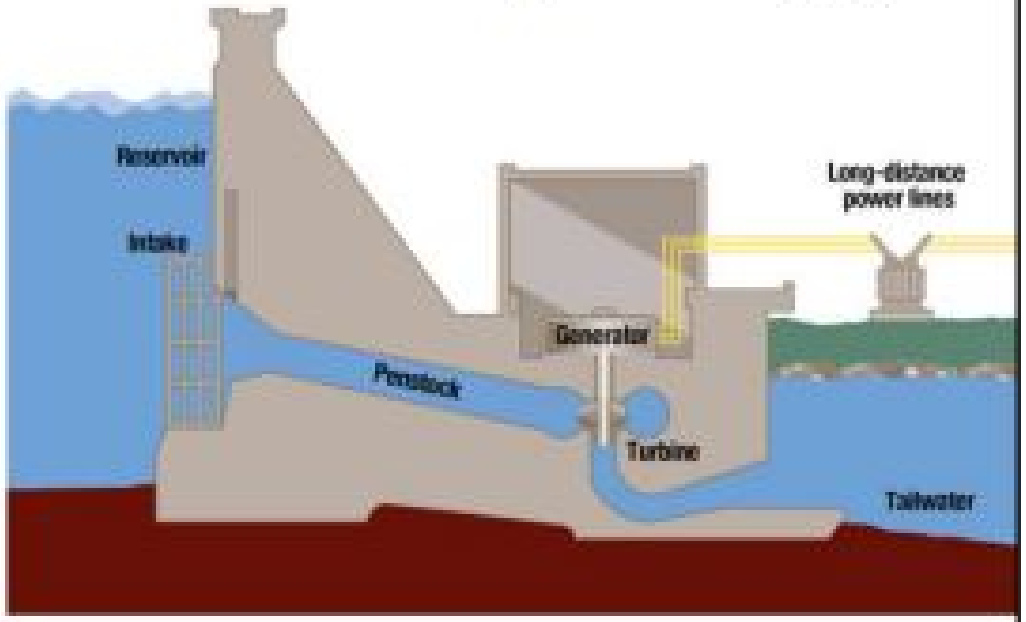
What do you mean by Hydropower?

ANY IDEA?

Hydropower

Hydropower is defined as the source of renewable energy formed by the movement of flowing mass of water on the surface of the earth. It gives number of times energy production without change of its physical properties.

In hydropower plant the water is utilized to move the turbines which in turn run the electric generators. The potential energy of the water stored in the dam gets converted into the kinetic energy of the moving water in the penstock.



And this kinetic energy gets converted into the electrical energy with the help of turbine and generator combination.

Power, $P = \rho_w \, g \, Q \, H \, \eta$ Watts

Energy:

Energy is defined as the total power consumed over a certain period, measured in Kilowatt-hours (kWh).

1 Kwh = 1 unit = Energy consumed when power is utilized at the rate of 1 kW for 1 hour.

Classification of Energy

1. Renewable Energy:

The source of energy which could be reused after its utilization is termed as renewable energy. Hydro, wind, tidal and solar energies are renewable energy. They are available in plenty and by far most the cleanest sources of energy available on this planet.

2. Non-Renewable Energy:

The source of energy which is converted into the unusable form after its utilization is termed as non-renewable energy. Fossil fuels (such as natural gas, oil and coal) are non-renewable energy. Non-renewable sources are not environmental friendly and can have serious affect on our health.

Sources of energy

Hydropower

Thermal power

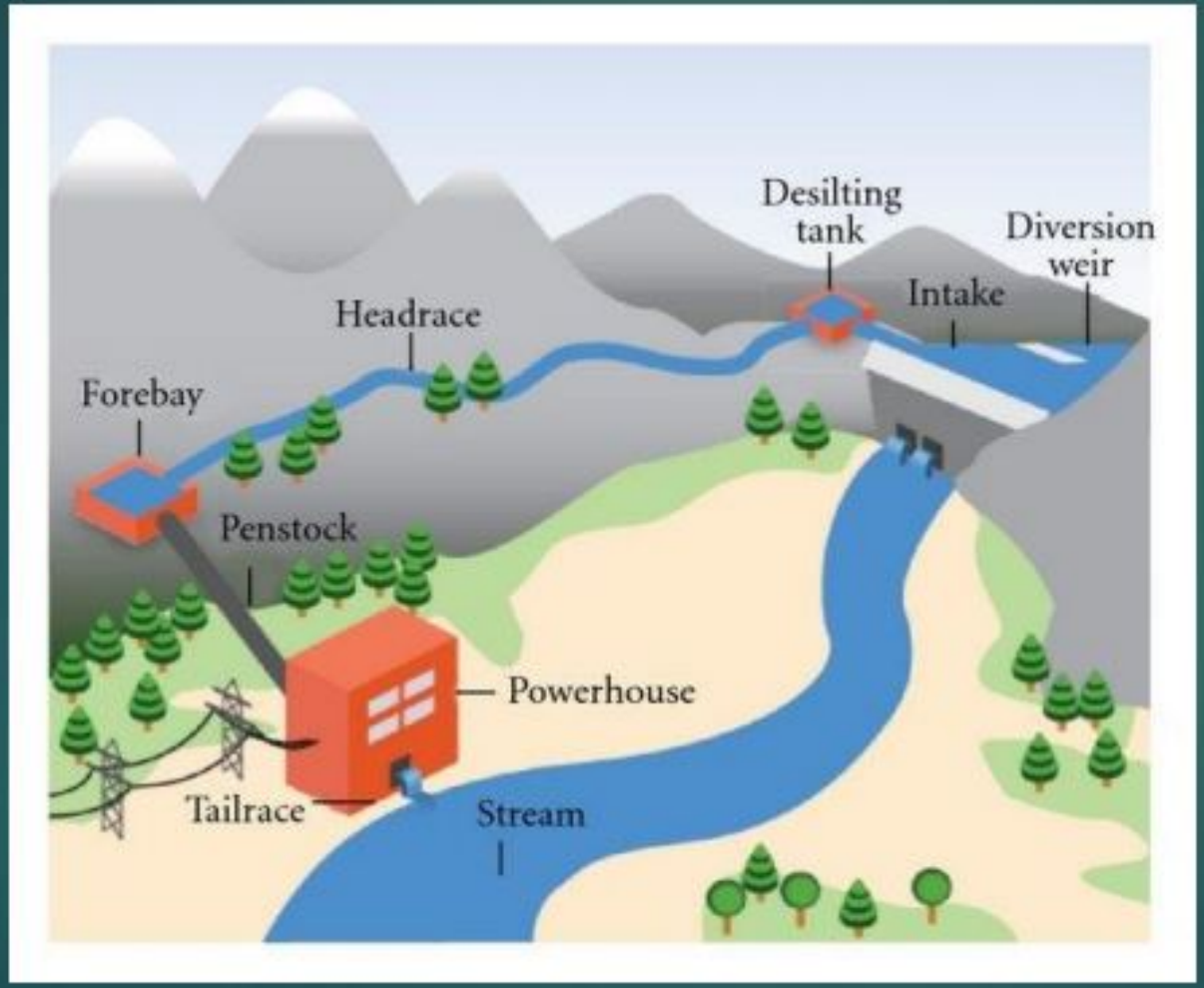
Nuclear power

Tidal power

Solar power

Geo-thermal power

Wind power


Desilting tank
Diversion weir
Intake
Headrace
Forebay
Penstock
Powerhouse
Tailrace
Stream

Advantages of Hydroelectric

Efficient

The most efficient method of power generation, more than 80%.

Maximizing Resource

Fast Startup

Startup in matter of minutes, suitable to during load peak supply.

Grid Balance and Stability

Clean Renewable Energy

No direct waste and carbon emission during power generation.

Environment Friendly

Hydropower Potential :

1. Gross potential:

The power which can theoritically be possible to generate is known as gross potential power.

A river basin is divided into several cascades. Based on the head and hydrograph of the particular cascade the power can be calculated. Then the total power in the river basin can be calculated using the following relation.

$$P = \sum_{i=1}^{n} \eta \gamma Q H / 1000$$

where, P = Power in MW

Q = Discharge in cumecs

H = Net head in m

γ = Sp. wt. of water in KN/m^3 ($9.81\ KN/m^3$)

η = Plant efficiency.

and n = Number of cascades.

- The estimated gross potential of Nepal = 83,000 MW.

2. Technical potential:

The power which is technically viable to produce is known as technical potential.

All the theoritically possible power in nature can't be produced due to various constraints like unfavorable geology, topography, climatic conditions, accessibility etc.

- Technical potential power in Nepal ≅ 44,000 MW

3. Economic potential:

The power which is economically feasible to produce is known as economic potential.

It is not always economical to utilize the discharge available during a short period of the year. The projects are usually considered economically feasible if the internal rate of return is higher than the prevailing interest rate and the benefit cost ratio is higher than unity.

- Estimated economic potential power in Nepal ≅ 42,000 MW.

Hydropower Potential of Nepal

Nepal has enormous potential of water resources. (How?)

Annual runoff only inside Nepalese territory- 175 billion cubic meters.

Including Tibetian Drainage- 200 billion cubic meters.

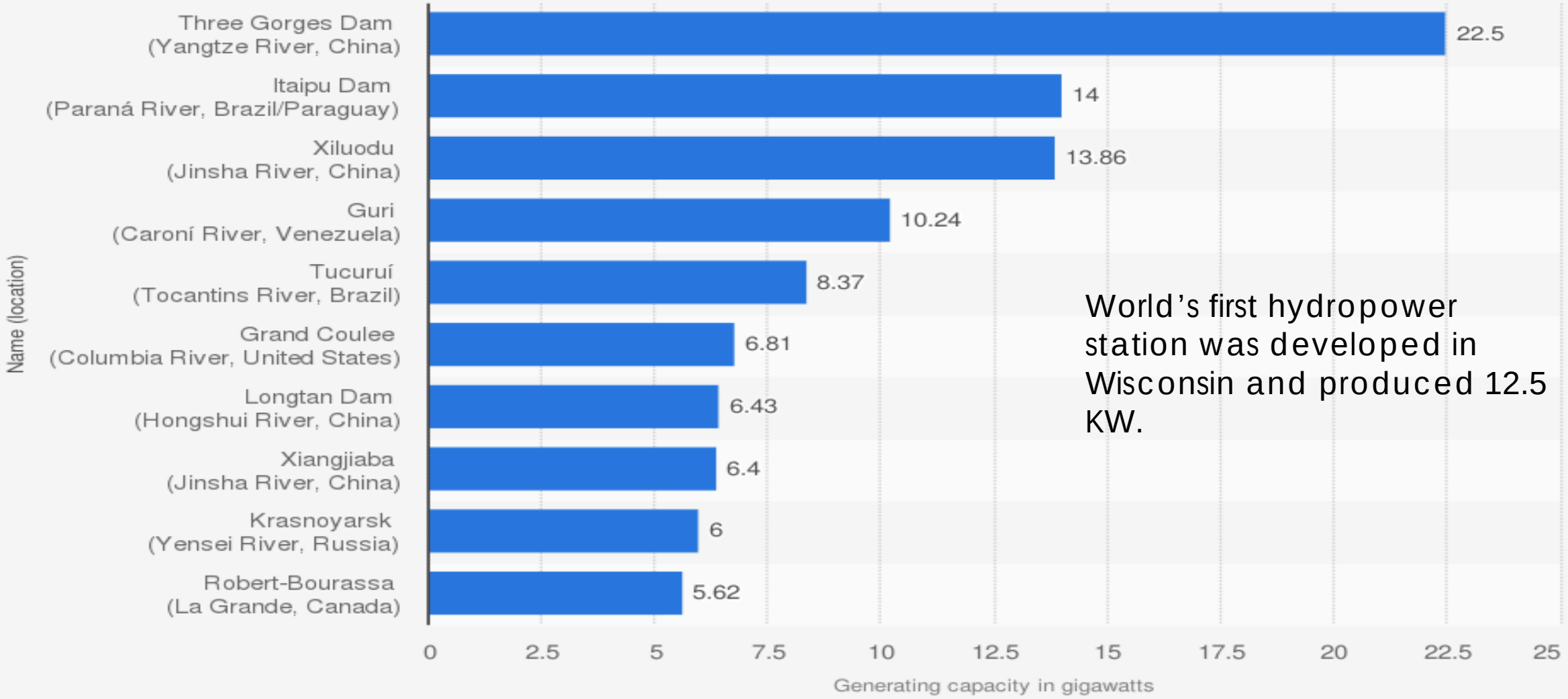
Topography changes from elevation 8848m to less than 100m within short distance of 160 km to 270km from North to South.

More than 6000 rivers and rivulets.

Hydropower Potential of Nepal

- Average annual precipitation is about 1500mm.
- Theoretical hydropower potential = 83000 MW.
- Economically feasible = 42000 MW.
- About 85% potential based on reservoir projects.

The world's largest hydroelectric dams as of 2019, based on generating capacity (in gigawatts)



World's first hydropower station was developed in Wisconsin and produced 12.5 KW.

Source
The News International
© Statista 2021

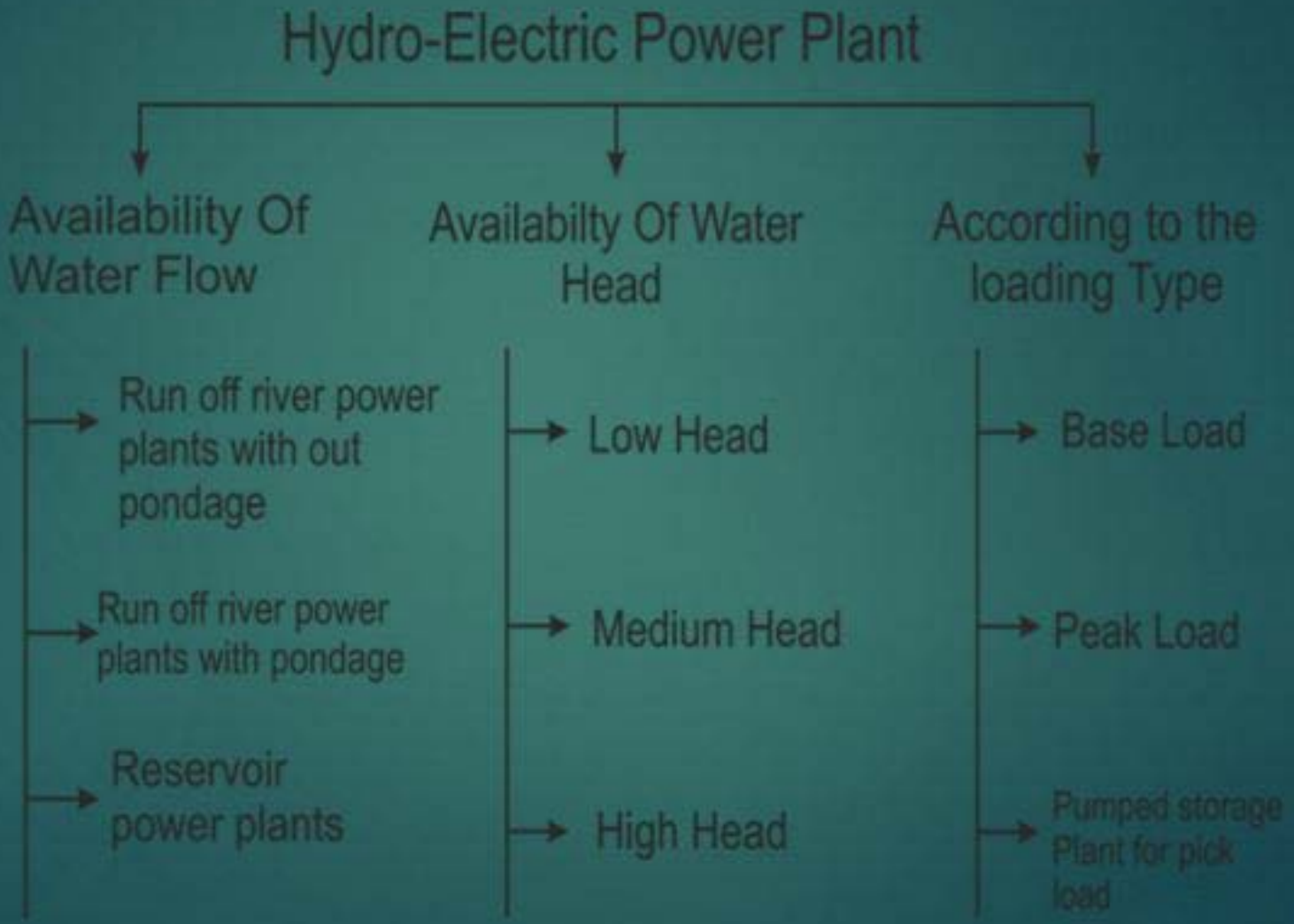
Additional Information:
Worldwide; as of May 2019

Total Units = 32 units having 700 MW each with 2 small generator having 50 MW capacity = 22500 MW
Constructed in Yangtze River

Upper Tamakoshi 456MW (4hrs-Peaking)

Upper Tamakoshi 456MW

Types of Hydroelectric Plant



- 1.3 Classification of Hydropower Plants as Low Head, Medium Head and High Head

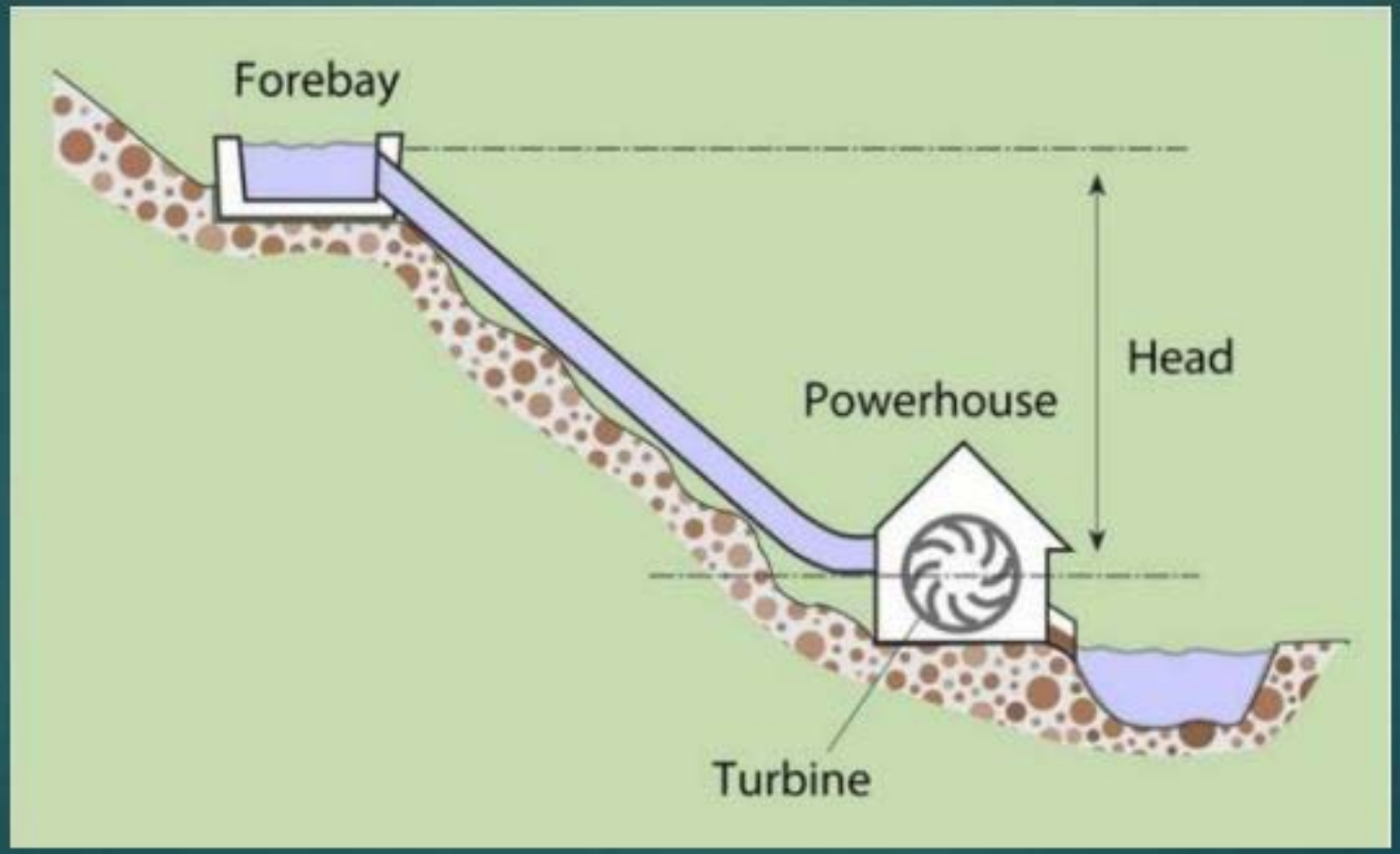
- Different countries classify the hydropower projects differently based on head of water. Generally they ar classified into three categories based on per height of water or water head:

1) Low Head:
   - Head of water under which it operates is upto 15 m (Head <=15m)

2) Medium Head:
   - Head of water under which it operates is in between 15 to 50 m i.e. (15 m <Head <= 50 m)

3) High Head
   - Head of water under which it operates is more than 50 m. (Head >=50 m)

Head for Hydroelectric plant



- But in Nepal, most of the projects have huge elevation differences between the headworks site and powerhouse site so the following classification for hydroelectric plants may be used:

a. Very Low Head

- Head of water under which it operates is upto 15 m (Head <=15m)
- Generally axial flow turbine like Kaplan Turbine is used.

b. Low Head

- Head of water under which it operates is between 15 m to 60 m (15 < Head<= 60)
- Kaplan or Francis Turbine can be used.

Gandak Hydro Power Station

c. Medium Head

- Head of water under which it operates is in between 60 to 150 m (60 < Head<= 150 m)
- Usually, Francis Turbine is adopted.

d. High Head

- Head of water under which it operates is between 150 m to 350 m (150 < Head<= 350 m)
- Pelton or Francis Turbine is adopted.

e. Very High Head:

- Head of water under which it operates is more than 350 m. (Head >= 350 m)
- Pelton Turbine is used.

Classification Based on Installed Capacity

1. Micro-Hydropower (upto 100KW)
2. Mini Hydropower (100KW-1000KW)
3. Small Hydropower (1MW-25MW)
4. Medium Hydropower (25MW-100MW)
5. Large Hydropower (>100 MW)

Classification Based on Operation

1. Isolated Plant : e.g. Micro hydropowers
2. Grid Connected : In Nepal, INPS (Independent National Power System), where all the projects are connected. The grid is owned by NEA and operated through load center at Swichatar, Ktm.

1.4 Runoff River, Storage and Pump Storage Plants

Runoff River hydropower

- In the run-of-river plants, electricity is generated as and when the water is available in the river. When the river dries up or the flow falls below some predetermined amount (minimum flow of the turbine), the electricity generation ceases (stops).
- Due to the large variation in flow in rivers in Nepal, these types of projects are normally designed for the dry season flows in the rivers.
- Suitable for perennial river having adequate discharge throughout the year.
- Minimum dry flow should be sufficient to run the turbine efficienctly and economically.
- For example: Bhotekoshi Hydroelectric Plant (36 MW), Indrawati –III (7.5 MW), Modi hydropower plant (14 MW), etc.

Examples:

1. Kulekhani II : 2*16 MW, Francis Turbine, commissioned in 1986.
2. Kulekhan III : 2*7 MW, Francis Turbine, commissioned in 2019.
3. Upper Trishuli 3A hydropower station (60MW): 2 units of each having capacity of 30 MW, Located in Rasuwa and Nuwakot district and commissioned in 2019.
4. Trishuli Hydropower Station (24MW): 6 units each 3.5 MW and 1 unit of 3 MW., Commissioned in 1967 AD, Francis Turbi
5. Devighat hydropower Station (14.1 MW): 3 no of units, cascade project of Trishuli hydropower station, commissioned in 1984 AD, Vertical Francis turbine used.
6. Gandak Hydropower Station (15 MW): 3 no of units each having 5 MW, kalplan turbo generator is used, located in Nawalparasi district, commissioned in 1979 AD.
7. Modi Khola Hydropower Station (14.8 MW): 2 no of units of each having 7.4 MW, two vertical shaft francis turbin used, located at Dimuwa in parbat district.

Pondage Runoff-River (PROR) Plant

→ Dam is constructed across the river to create a peaking reservoir in its U/s.

→ Sometimes the peaking pond is also constructed after the settling basin.

→ water is stored in the peaking reservoir/pond for few hours when the demand is low and also called off peak hours and released at peak time.

→ storage hours may vary as per load demand and water availibility in the river.

① Daily peaky or Daily storage or peaking Run of River (PROR) plant.

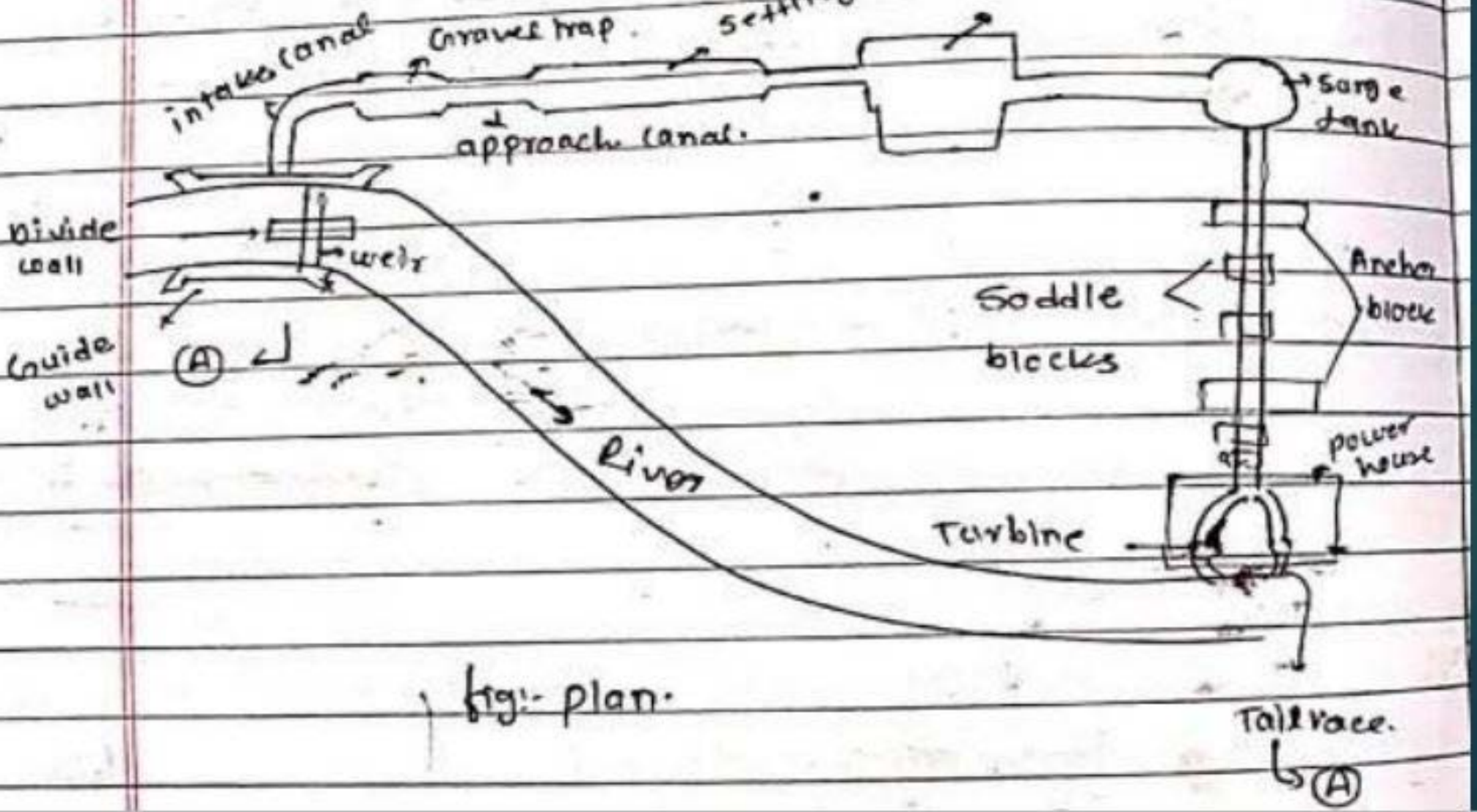
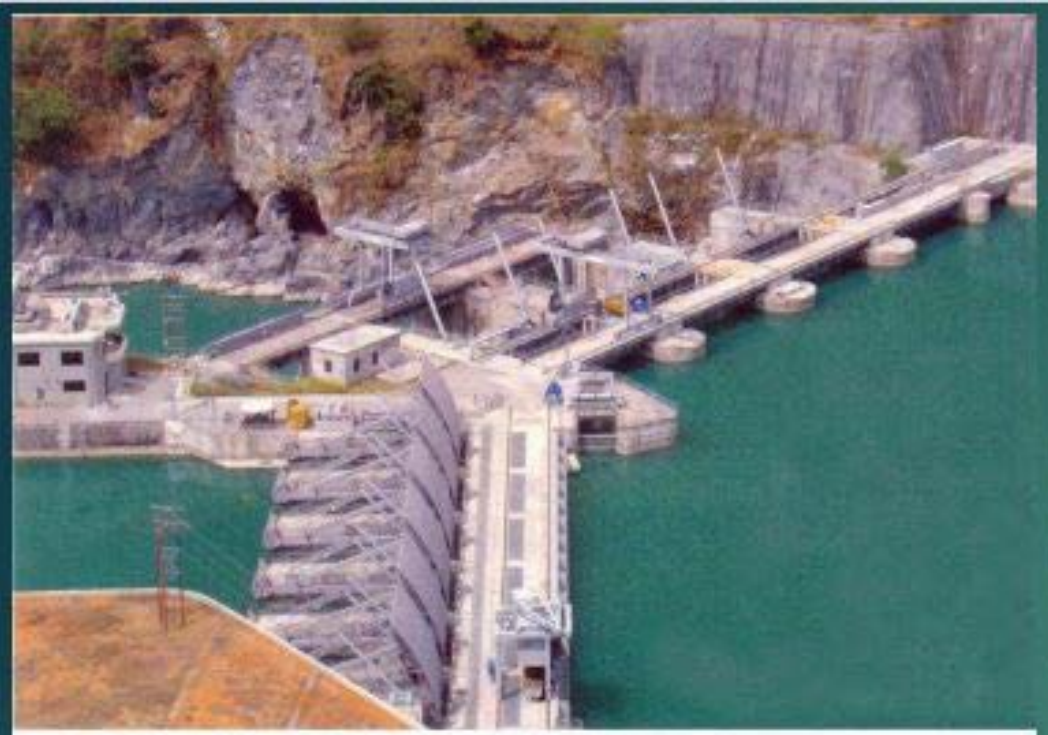
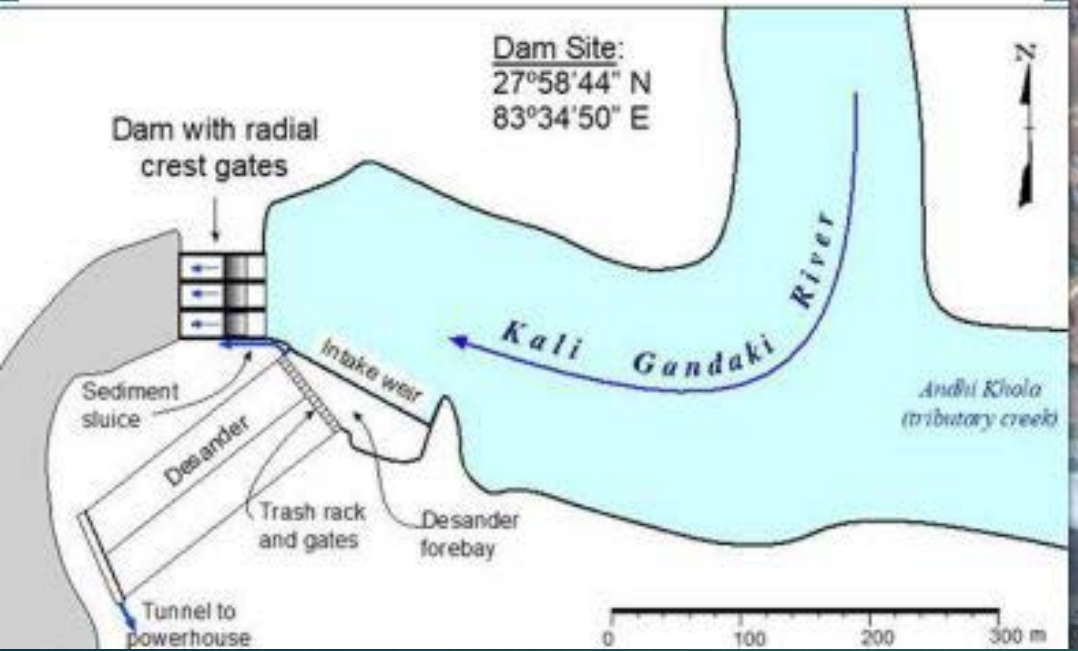


fig:- plan.



Headworks and Intake Structure of Kali Gandaki -A HEP(144MW)



Peaking Hydropower Projects of Nepal

1. Kali Gandaki 'A' Hydropower Station (144 MW) : (3 Units each having capacity 48 MW), Located Beltari, Syangja and commissioned in 2002 AD.

    6-hrs daily peaking

2. Middle Marsyangdi Hydropower Station (70 MEW) : (2 Units each having capacity 35 MW), Located at Lamjung and commissioned in 2008 AD.

    5-hrs daily Peaking

3. Marsyangdi Hydropower Station (69 MW) : (3 Units each having capacity 26 MW), Located Aanbukhaireni, Tanahu District and commissioned in 1989)

    4-hrs daily peaking

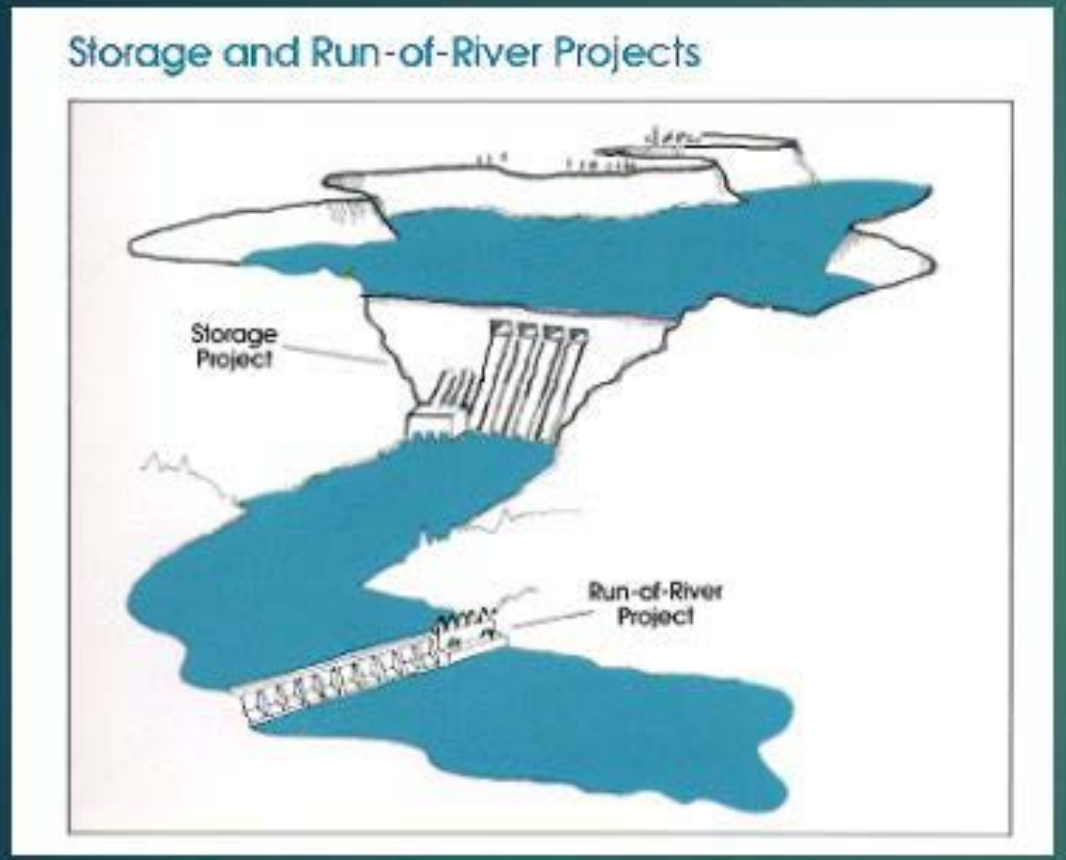
4. Upper Tamakoshi Hydropower Station (456 MW) : (6 units each having 76 MW, 4 hrs peaking, located at Dolakha District, gross head 822 m, design discharge 66 m3/s, pelton turbine used, live storage 1.2 Million m3.

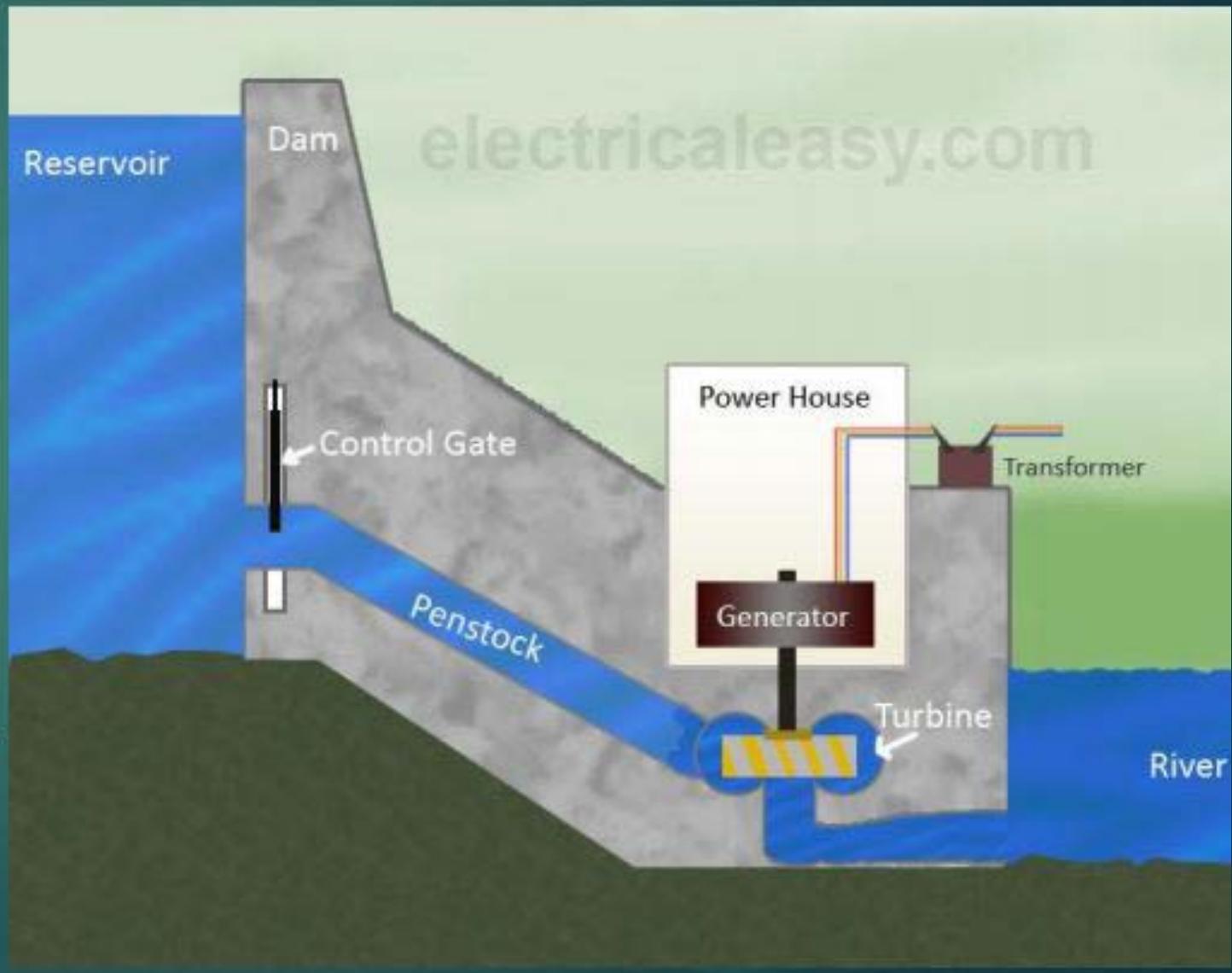
- Constructed by SPV Company
- Promoter Share (51%): NEA 41%, Nepal Telecom 6%, Rastriya Beema Sansthan 2%, Citizen Investment Trust 2%.
- Public Share (49%): Employee of equity provider 24%, general public 25% (local 15%)
- Debt: Equity = 70:30
- Head- 822m, Pelton Turbine
- Qd= 66 m3/s

Storage type hydropower

- Storage Plants have enough storage capacity to offset seasonal fluctuations in water flow and provide a constant supply of electricity throughout the year.
- Most of the rivers of Nepal have huge amount of flow variation in rainy (monsoon season) and dry season. Due to such variation, the power generation during dry season is quite low while designing run-off-river schemes.

Storage type hydropower

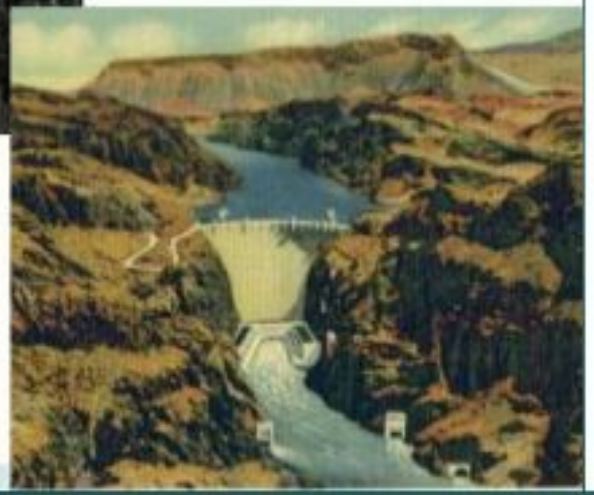




- The excess water in the river during rainy season is stored by constructing a dam and reservoir in order to generate electricity during dry season (winter).
- Large dams can store several years' worth of water.
- Can also be constructed in non perennial rivers.
- Power house may be located at the toe of the dam or away from the dam.
- For example: Kulekhani – I (60 MW), Budhigandaki Hydroelectric Plant (650 MW), etc.

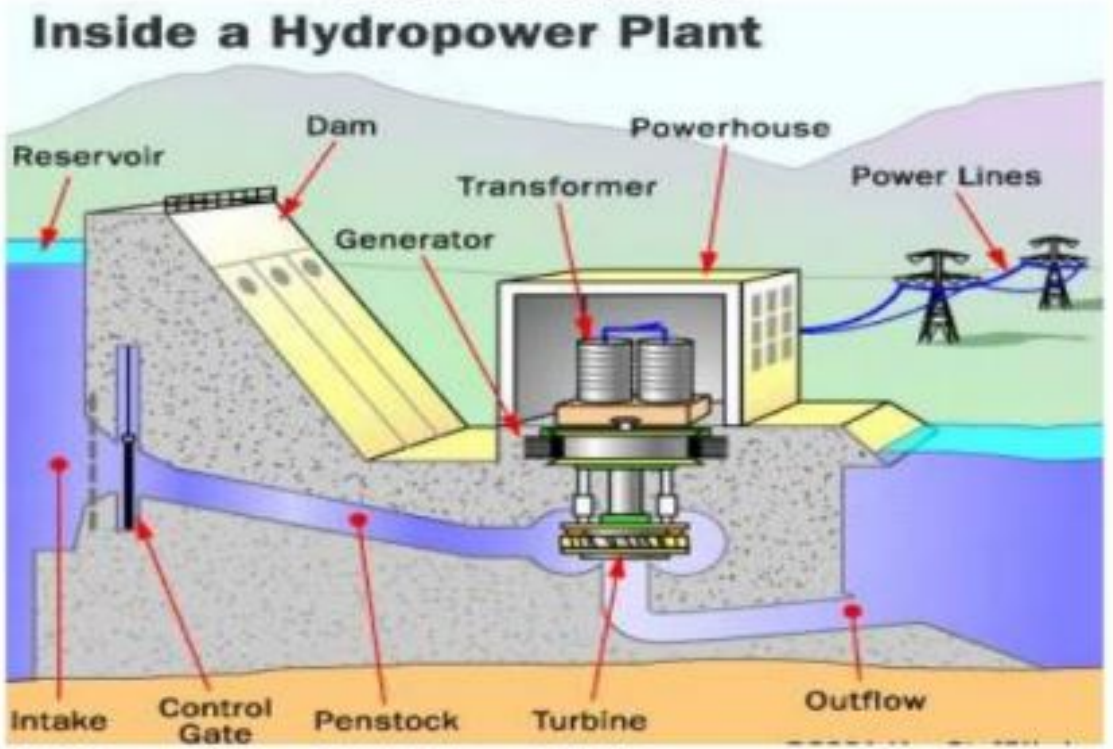
Kulekhani – I hydropower Station (60 MW): Located at Makwanpur district, 2 Units each having 30 MW
Rock Fill Earthern Dam (114m), Total reservoir capacity = 85,300,000 m3, Comissioned in 1982 AD, Head = 550m, pelton turbine)

← Before the Construction of the Dam



After construction of the Dam →

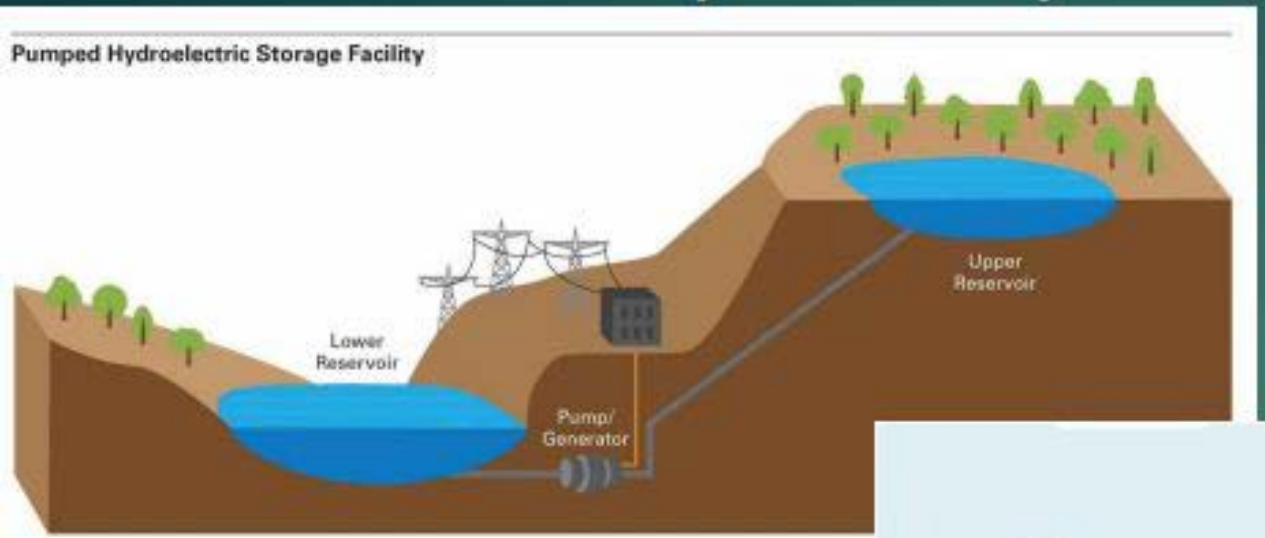
How it Works



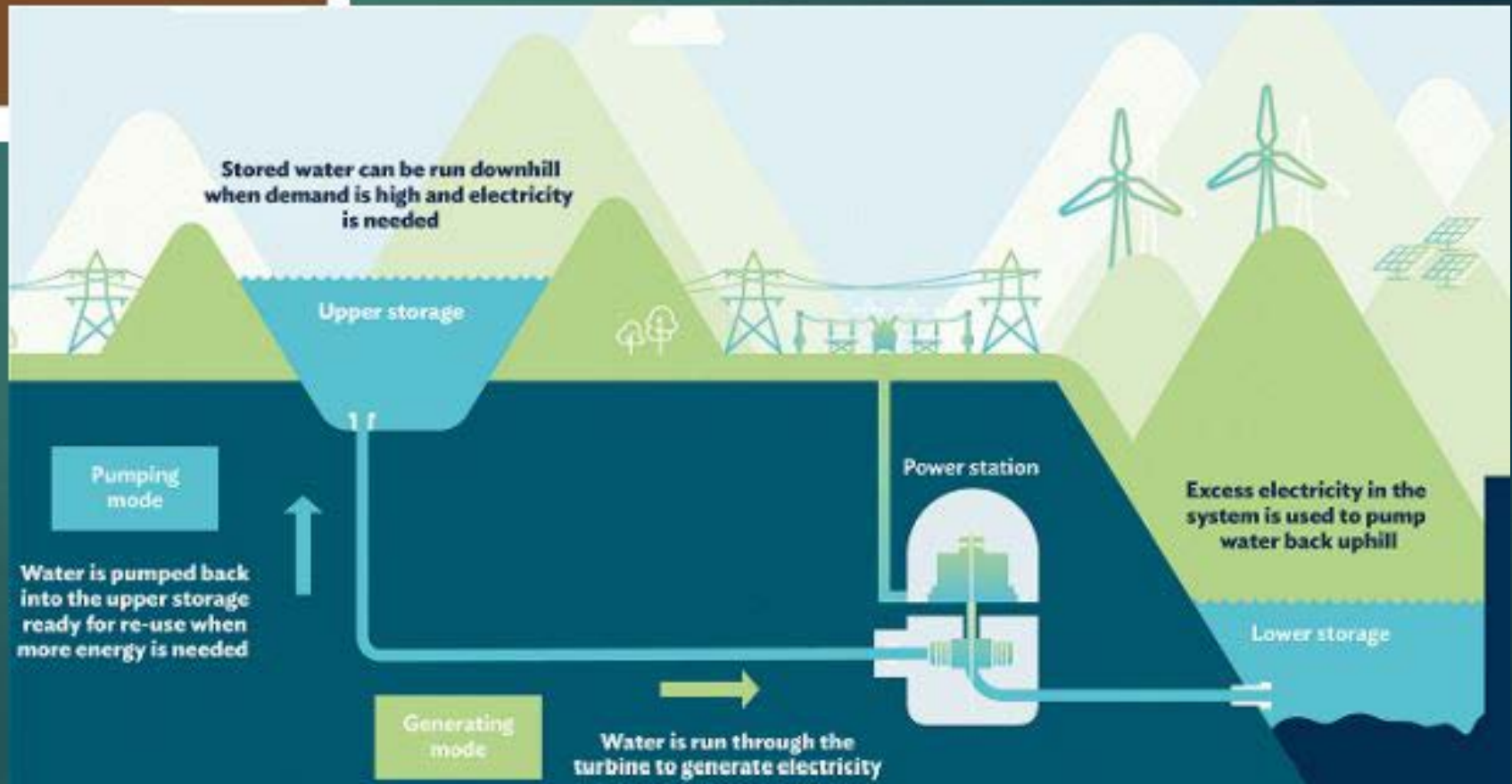
Pump Storage Plants

- In contrast to conventional hydropower plants, pumped storage plants reuse water.
- After water initially produces electricity, it flows from the turbines into a lower reservoir located below the dam.
- During off peak hours (periods of low energy demand), some of the water is pumped into an upper reservoir and reused during periods of peak demand.
- Generates power only during peak hours.
- It provides additional capacity/ power to meet peak demand.
- Comparatively expensive
- No such plant in Nepal till date.

Pumped Hydropower



On going project: Kulekhani Sisneri Pump stotage project, Begnas Rupa pump storage project.


Stored water can be run downhill when demand is high and electricity is needed
Upper storage
Pumping mode
Water is pumped back into the upper storage ready for re-use when more energy is needed
Power station
Excess electricity in the system is used to pump water back uphill
Lower storage
Generating mode
Water is run through the turbine to generate electricity

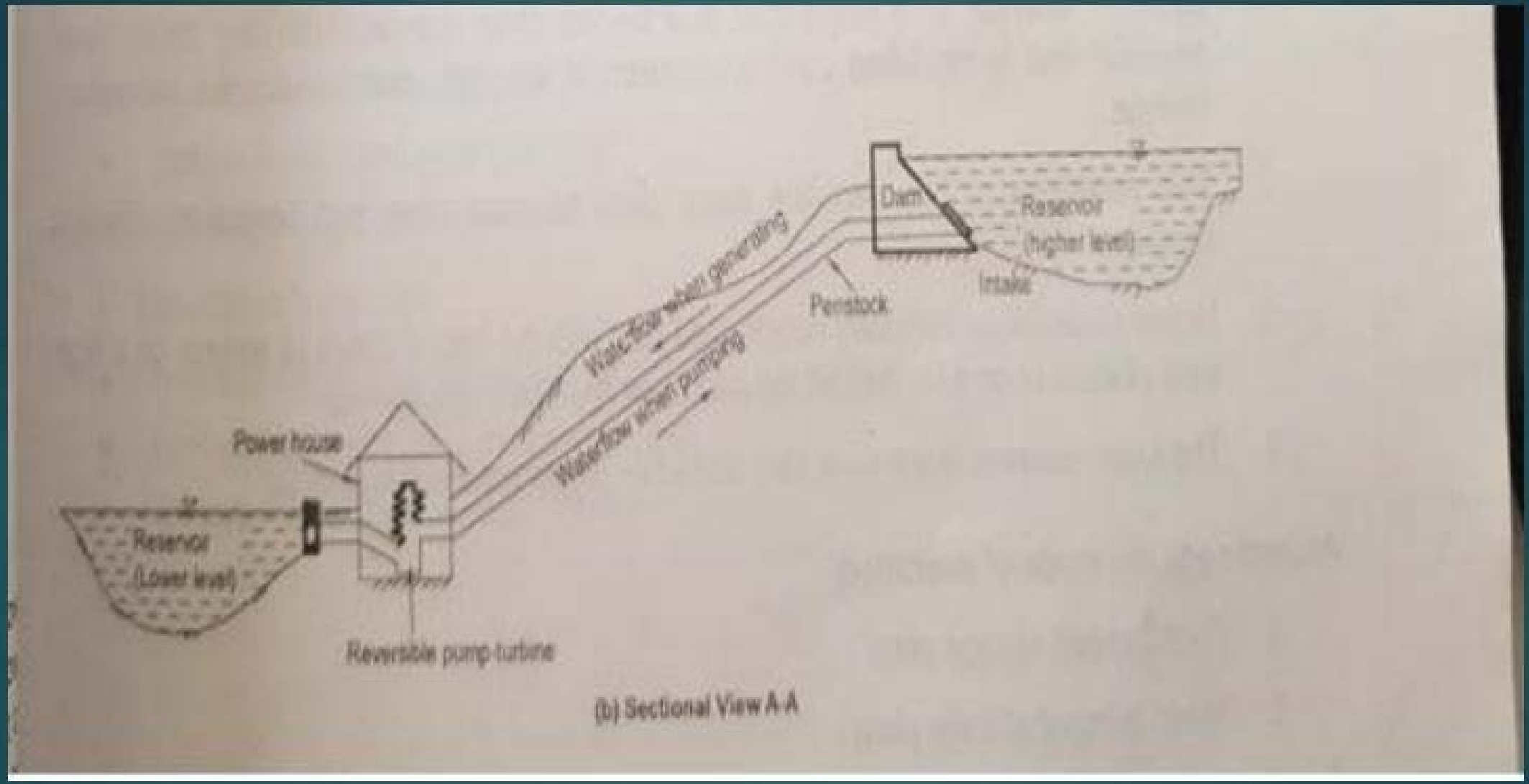
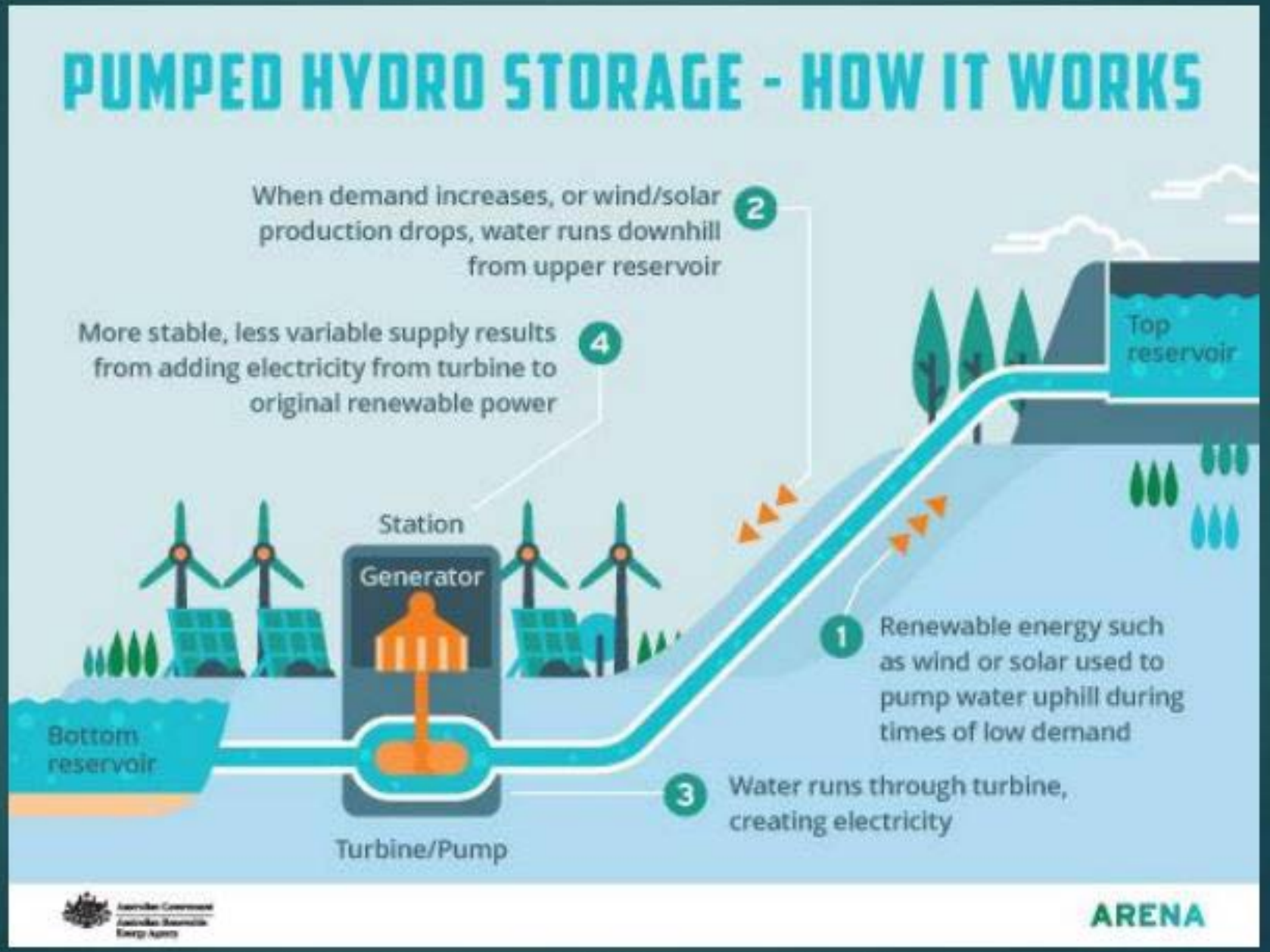


Fig: Typical Layout of Pump Storage Plant

Combination of pumped and renewables


PUMPED HYDRO STORAGE - HOW IT WORKS
When demand increases, or wind/solar production drops, water runs downhill from upper reservoir
2
More stable, less variable supply results from adding electricity from turbine to original renewable power
4
Top reservoir
Station
Generator
1
Renewable energy such as wind or solar used to pump water uphill during times of low demand
Bottom reservoir
3
Water runs through turbine, creating electricity
Turbine/Pump
ARENA

History of Power Sector Development in Nepal

- Farping (500 KW) was a model project in Asia (7 lakhs, 17 months): 1911 AD
- Sundarijal (640 KW) was another achievement before world war II (1936 AD) used for water supply in ktm valley after discharged from tailrace.
- In the tenure of Sri 3 Juddha Samser, Morang Hydropower Company (MHC) was established under the planning of Bijay Samser with Padma Sundar Malla as the Chief Engineer: 1939 AD
- Letang HPP (1800 KW) was constructed by MHC which mainly supplied Biratnagar Jute mill: 1942 AD
- Letang HPP was never rehabilitated after it became defunction in the course of time
- MHC also established various diesel plants in different parts of Terai.

History of Power Sector Development in Nepal

- Panauti HPP (2.4 MW) : 1965, First 33 KV transmission line was also constructed during this year
- Phewa HPP (1090 KW) :1967
- Trishuli (24 MW): 1968 AD
- Subsequent development of Sunkoshi(10 MW), Tinau(1 MW), Gandak(15 MW), Kulekhani I(60 MW), Devighat(14.1 MW), Seti(1.5 MW), Kulekhani II(32 MW), Marsyandi(69 MW) were carried out till 1989 AD and a total of only 249 MW was achieved
- Andhikhola(5.1 MW), Jhimruk (12 MW) and Chatra(3.2 MW) were some other additions during 8th plan period (1991/92-1996/97) making the total installed capacity of around 269 MW which was again a very slow progress

History of Power Sector Development in Nepal

- After 1990, Government invited private sector also for power development through electricity act 1992 and hydropower development policy 1992 to address the problem of monopoly in generation and distribution and to introduce competition in electricity sector.
- After the promulgation of these acts and policies , private sector showed remarkable interest in hydropower development and accordingly Khimti (60 MW), Bhotekoshi (36 MW) and Indrawati (7.5 MW) were brought into the system during 9th plan period (1997/98-2002/03).
- During the same 9th plan period Govt/NEA developed Puwakhola(6.2 MW), Modi(14 MW), Kaligandaki A (144 MW). Altogether a total of 290 MW was developed in the 9th period with the effort of both private and public sector. By the end of 9th period, the total installed capacity of hydropower was 537MW.
- 9th plan period was the most successful period of hydropower development when 46.2 % progress was achieved .

History of Power Sector Development in Nepal

- 10th plan period (2003/04-2008/09) had a bitter experience in terms of power generation. Only about 36 MW (Chilime: 22.1 MW, Sunkoshi: 2.5 MW, Piluwa khola: 3 MW, Chaku: 1.5 MW, Baramchi: 1 MW, Khudi: 4 MW by private sector and Tatopani: 2 MW by the Government) was added into the system against a target of 315 MW. Total hydropower capacity upto 10th period was 573 MW

- The reason of this snail pace progress might be the internal conflict and government's policies just in paper, not in practice. The worst progress of this period (only 4 %).

History of Power Sector Development in Nepal

- 11th plan period (3 year interim plan, 2009/10-2011/12) did not achieve virtually anything against target of 2115 MW. Only 70 MW middle Marsyangdi came into operation which was actually to be commissioned during 10th plan period.

- In addition to above mentioned projects, 32 small hydro project of 8 MW from the government and 12 SHPs of 6 MW from the private sector were added in the system in different periods of time.

- With the thermal plants (Duhabi: 39 MW and Hetauda: 14.4 MW and with the addition of some private projects in the this time, the total installed capacity has reached to 832MW.

History of Power Sector Development in Nepal

From 2012 to 2021 major achievement from NEA

- Upper Trishuli 3A(UT3A), 60 MW, 2019
- Chameliya Hydropower Station:- 30 MW, 2018
- Kulikhani lll Hydropower Station:- 14MW, 2078 BS
- With the addition of a generation capacity of 735 MW, including NEA's solar power into the system in Fiscal Year (FY) 2021/22.

On 2022:

Upper Tamakoshi HEP = 456 MW ,(P-RoR) 4hrs Peaking

Gross Head = 822 m

Design Discharge = 66 m3/s

Live Storage = 1.2 Million M3

No of Units = 6

Total Installed Capacity of Nepal 2022

- Total major hydro (NEA) grid connected = 578.624 MW
- Total Small hydro (NEA)- Isolated = 4.536 MW
- Total NEA= 583.16 MW
- Total Hydro NEA subsidiary company = 478.100 MW (Chilime hydro power ltd 22.1 MW + Upper Tamakoshi hydropower ltd 456 MW)
- Total Hydro IPP = 1020.528 MW (122 IPP Projects)
- Total Hydro (NEPAL) = 2081.788 MW
- Total Thermal (NEA) = 53.41 MW
- Total Solar (NEA) 21.58MW
- Total Solar (IPP) = 33.14 MW (8 IPP solar Projects)
- Total Installed Capacity (Isolated + grid connected) = 2189.918 MW

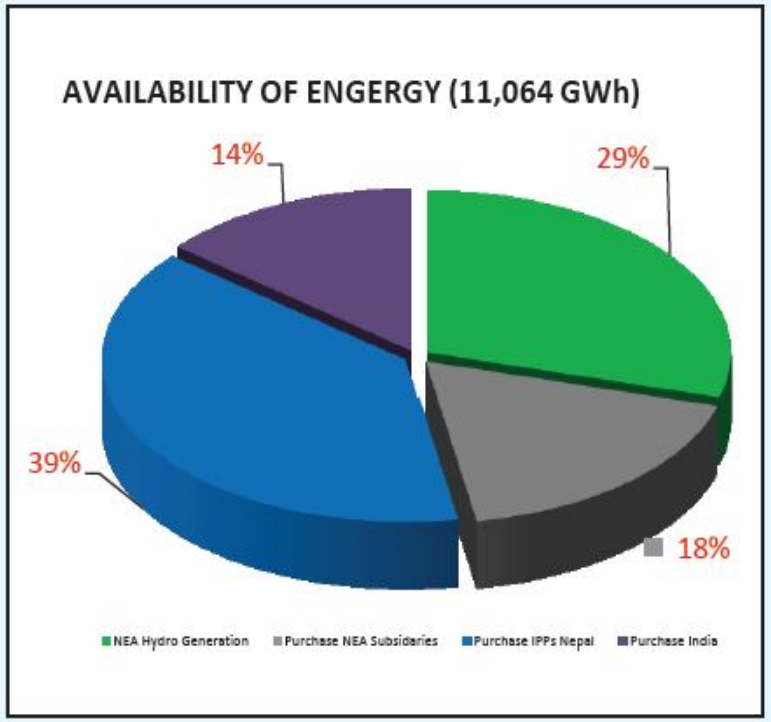
Under Construction Power Plant with Capacity

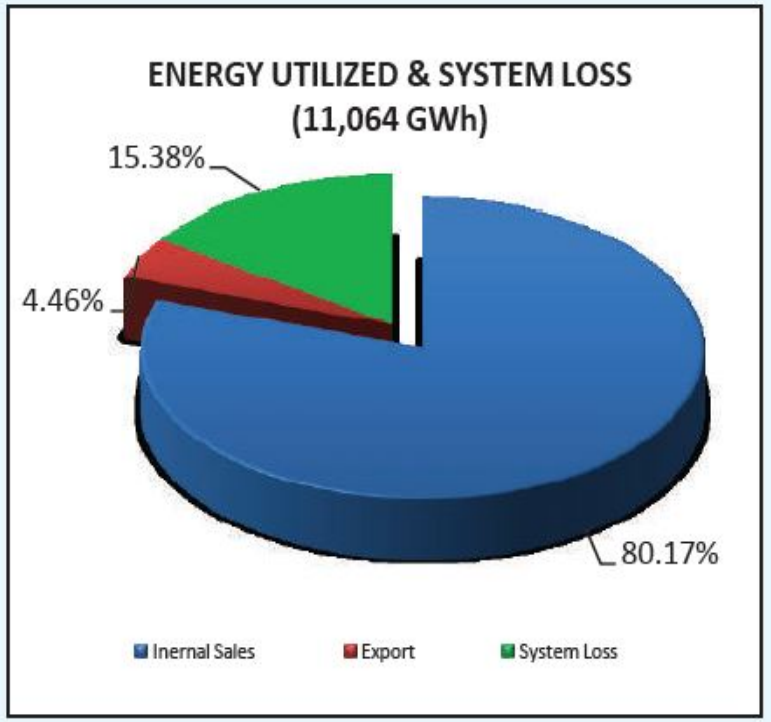
1. Tanahu Hydropower Project = 140 MW
2. Rasuwagadi = 111 MW
3. Sanjen = 42.5 MW
4. Rahuganga HEP = 40 MW
5. Upper Trishuli 3B = 37 MW
6. Upper Sanjen = 14.6 MW
7. Total = 487.1 MW (From NEA)

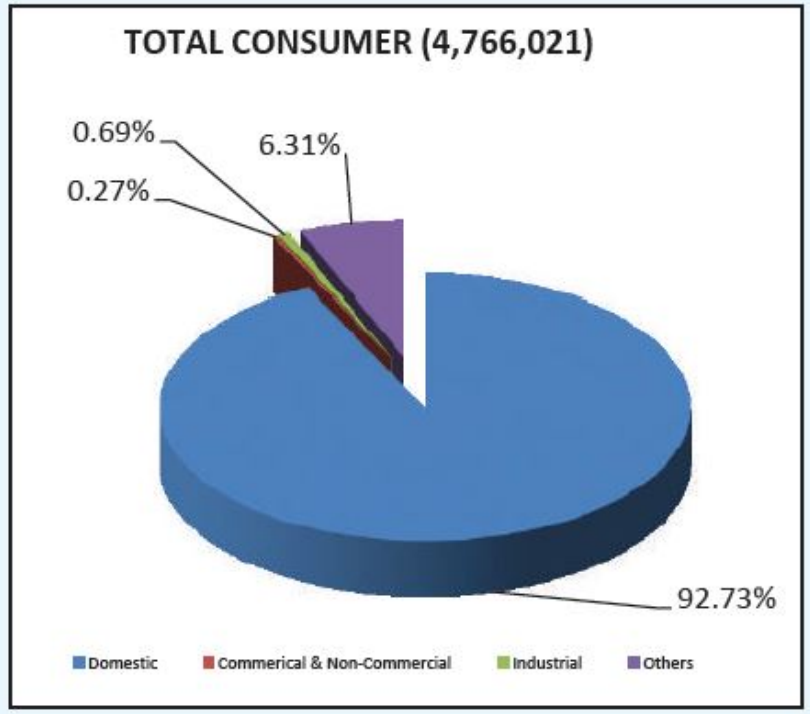
Planned and Proposed HEP

1. Upper Arun HEP = 1061 MW
2. Uttar Ganga Storage HEP = 828 MW
3. Dudkoshi Storage HEP = 635 MW
4. Chainpur Seti HEP = 210 MW
5. Aadhikhola Storage HEP = 180 MW
6. Begnas Rupa Pump Storage HEP = 150 MW
7. Tamakoshi – V HEP = 95 MW
8. Upper Modi A HEP = 42 MW
9. Upper Modi HEP = 18.2 MW

It is encouraging to mention here that Government of India (GoI) has granted concurrence to Nepal for the export of about 364 MW of power from various hydropower projects and, accordingly, NEA has been exporting the same through Dhalkebar-Muzaffarpur 400 kV transmission line to the Day-Ahead Market of Indian Energy Exchange (IEX).

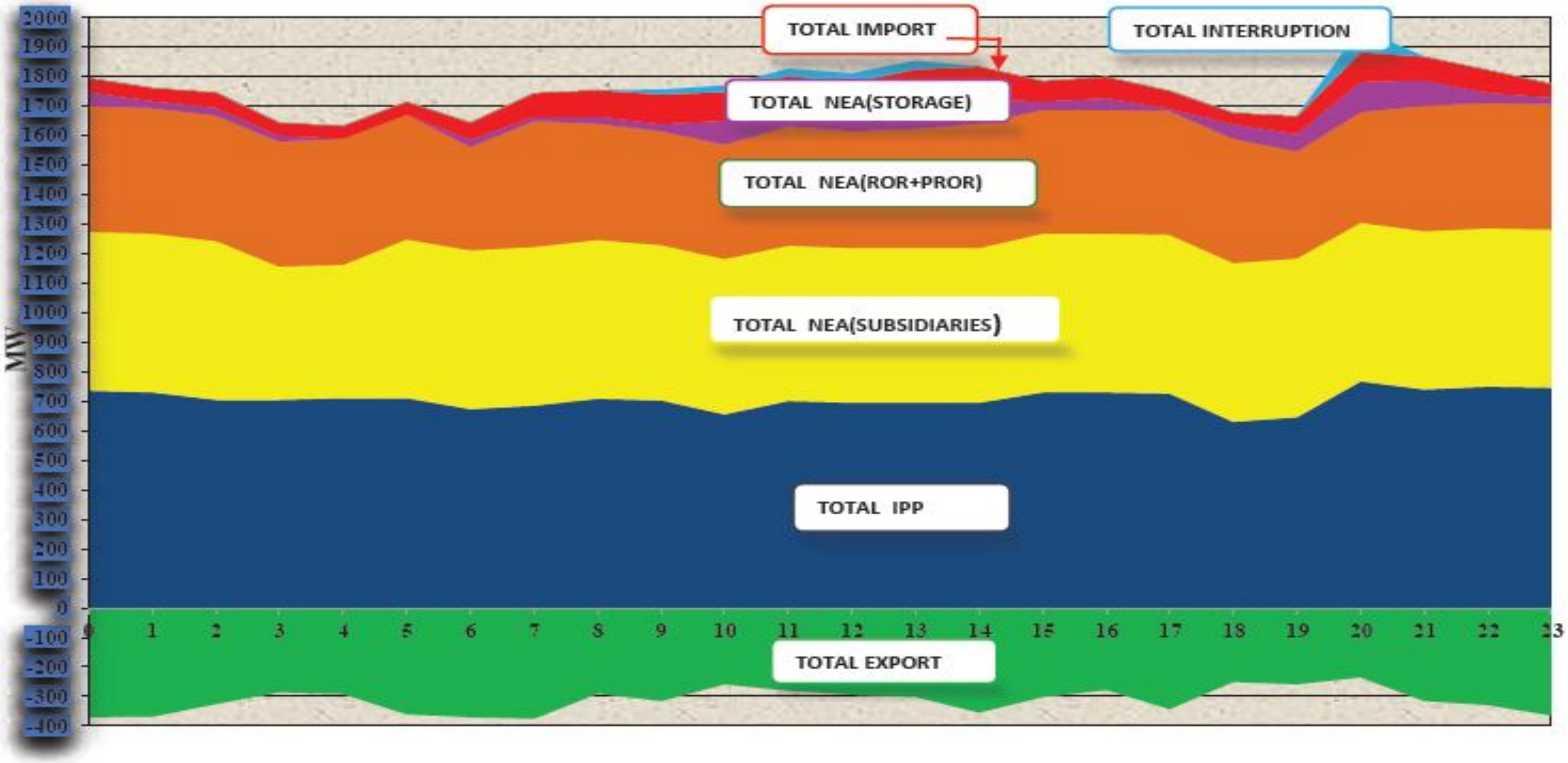

AVAILABILITY OF ENGERGY (11,064 GWh)
14%
29%
39%
18%
NEA Hydro Generation
Purchase NEA Subsidaries
Purchase IPPs Nepal
Purchase India


ENERGY UTILIZED & SYSTEM LOSS
(11,064 GWh)
15.38%
4.46%
80.17%
Inernal Sales
Export
System Loss

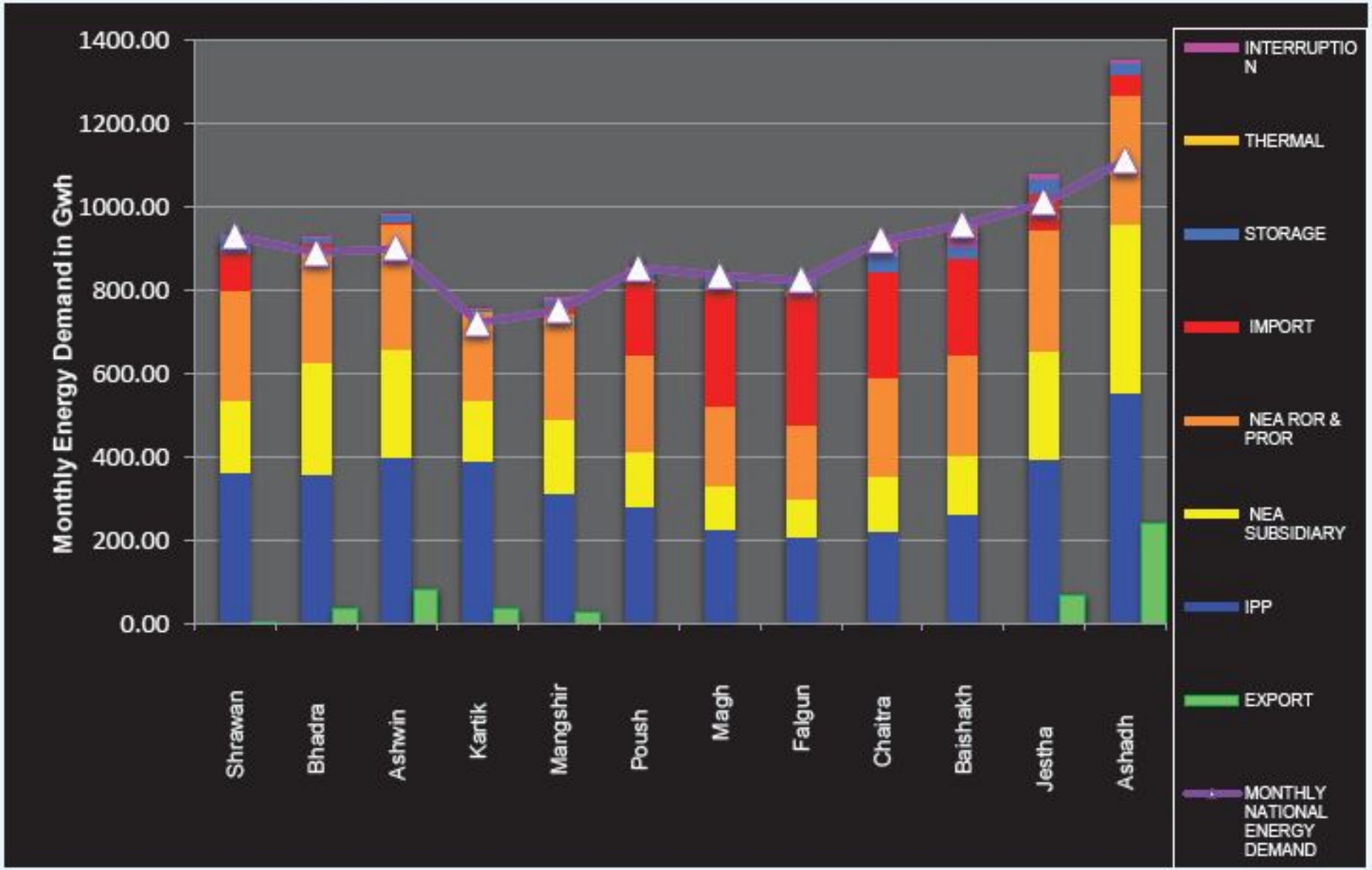

TOTAL CONSUMER (4,766,021)
0.69%
6.31%
0.27%
92.73%
Domestic
Commerical & Non-Commercial
Industrial
Others

System Load Curve (Maximum Demand) Asar 22, 2079
(July 6, 2022) Wednesday

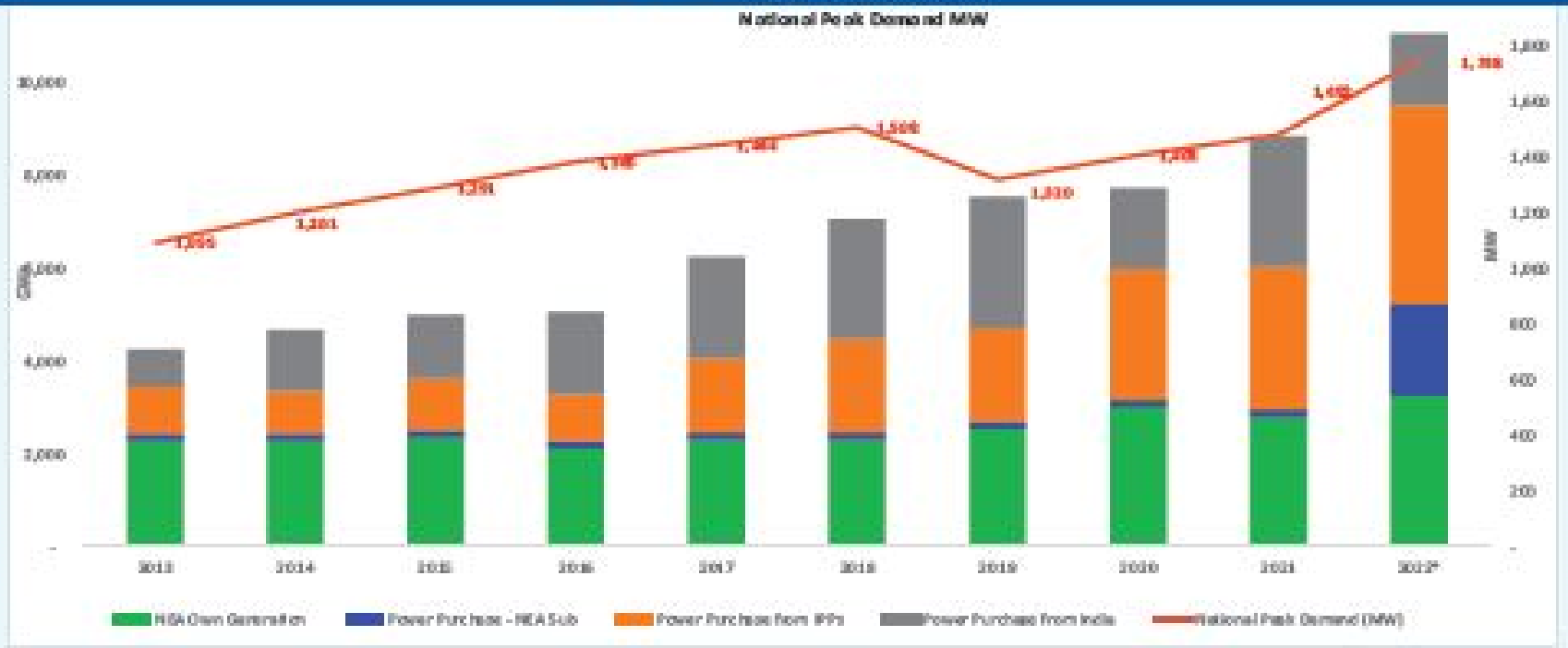
Annual System Peak Load 1963.98 MW at 19:50 hr



Energy Balance (GWh) in FY 2078/79 (2021/22)



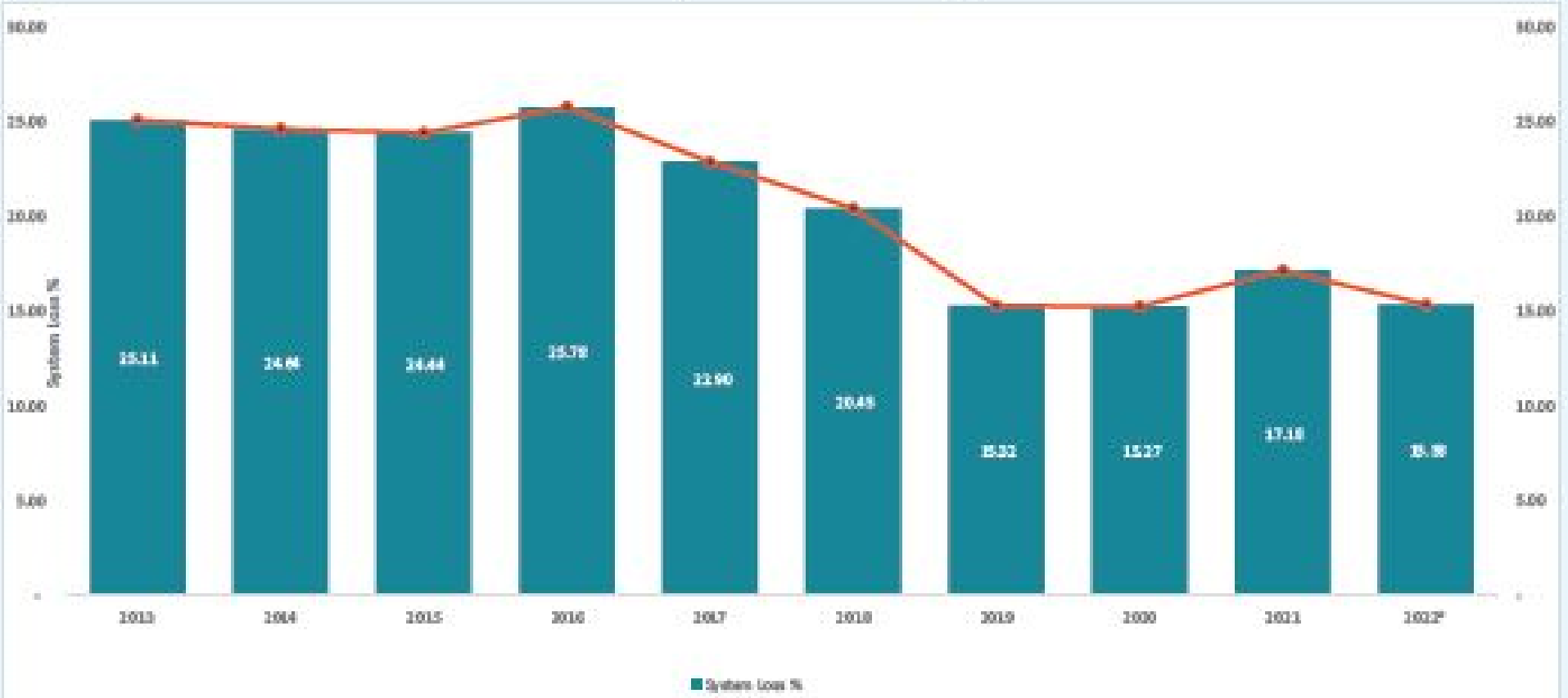
Total Energy Available & Peak Demand



Particulars	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*
Availability (GWh)										
NEA Own Generation	2,292	2,398	2,368	2,183	2,305	2,308	2,548	3,021	2,804	3,259
Power Purchase - NEA Sub	154	151	147	154	155	149	157	155	148	1,976
Power Purchase from IPPs	1,022	919	1,122	1,012	1,623	2,019	2,033	2,836	3,093	4,286
Power Purchase from India	790	1,319	1,370	1,778	2,175	2,582	2,813	1,729	2,806	1,543
Total Availability (GWh)	4,258	4,687	5,007	5,077	6,258	7,058	7,551	7,741	8,851	11,064
National Peak Demand (MW)	1,095	1,201	1,291	1,385	1,444	1,508	1,320	1,408	1,482	1,748
System Peak Demand Including Export (MW)										1,964
* Provisional Figures (Subject to audit)										

Nepal Electricity Authority

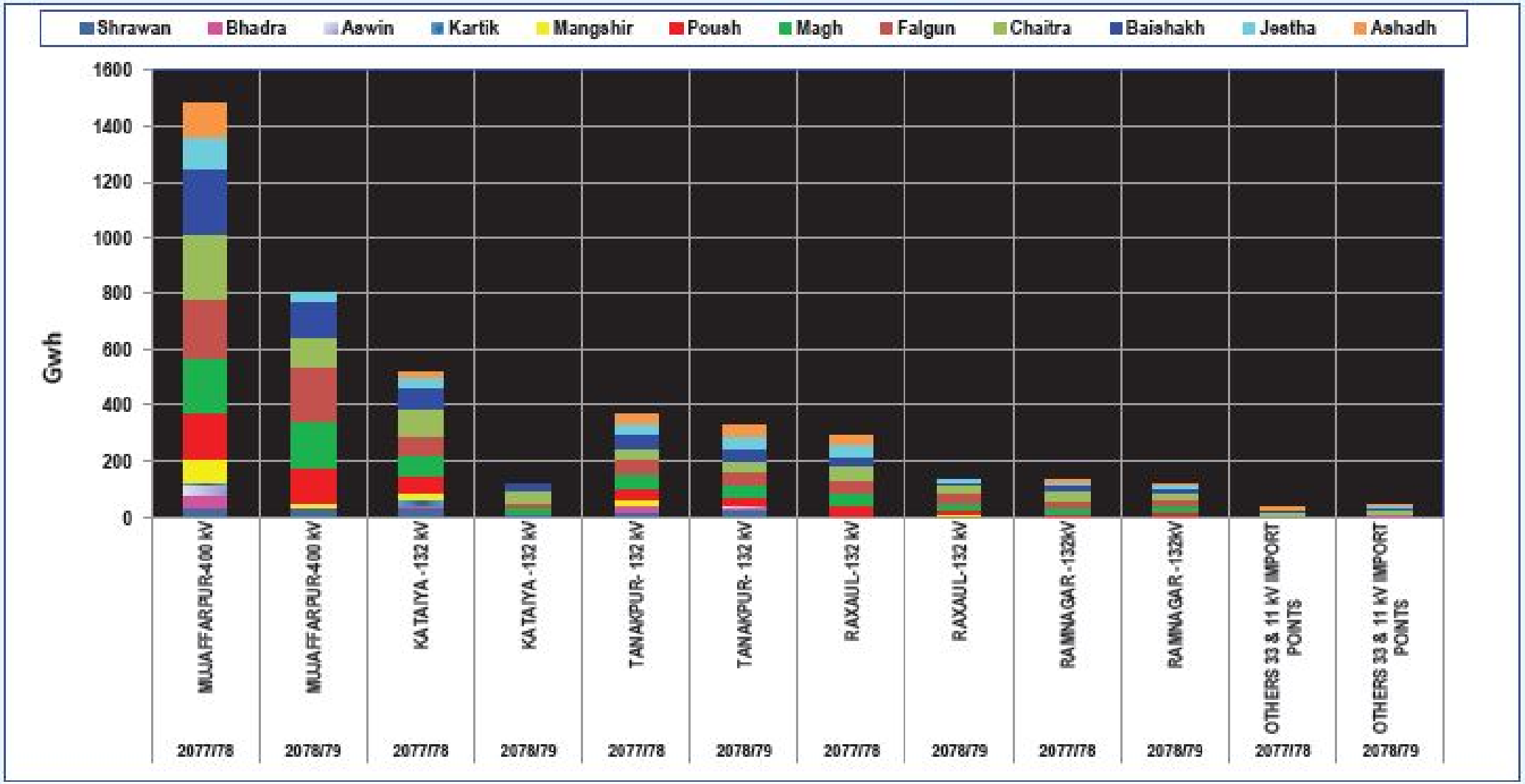
System Loss with Changes



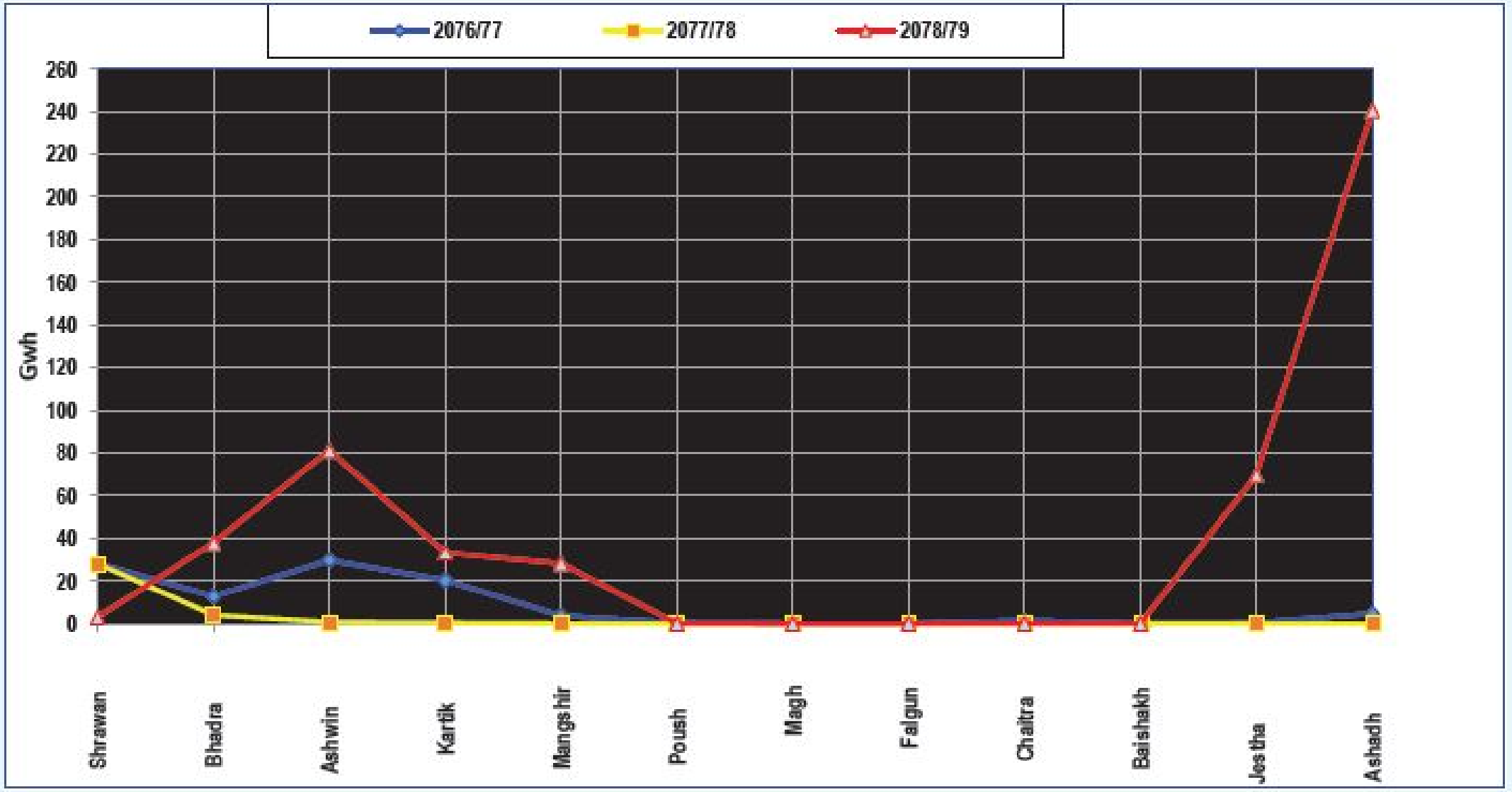
Particulars	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*
System Loss %	25.11	24.64	24.44	25.78	22.90	20.45	15.32	15.27	17.18	15.38

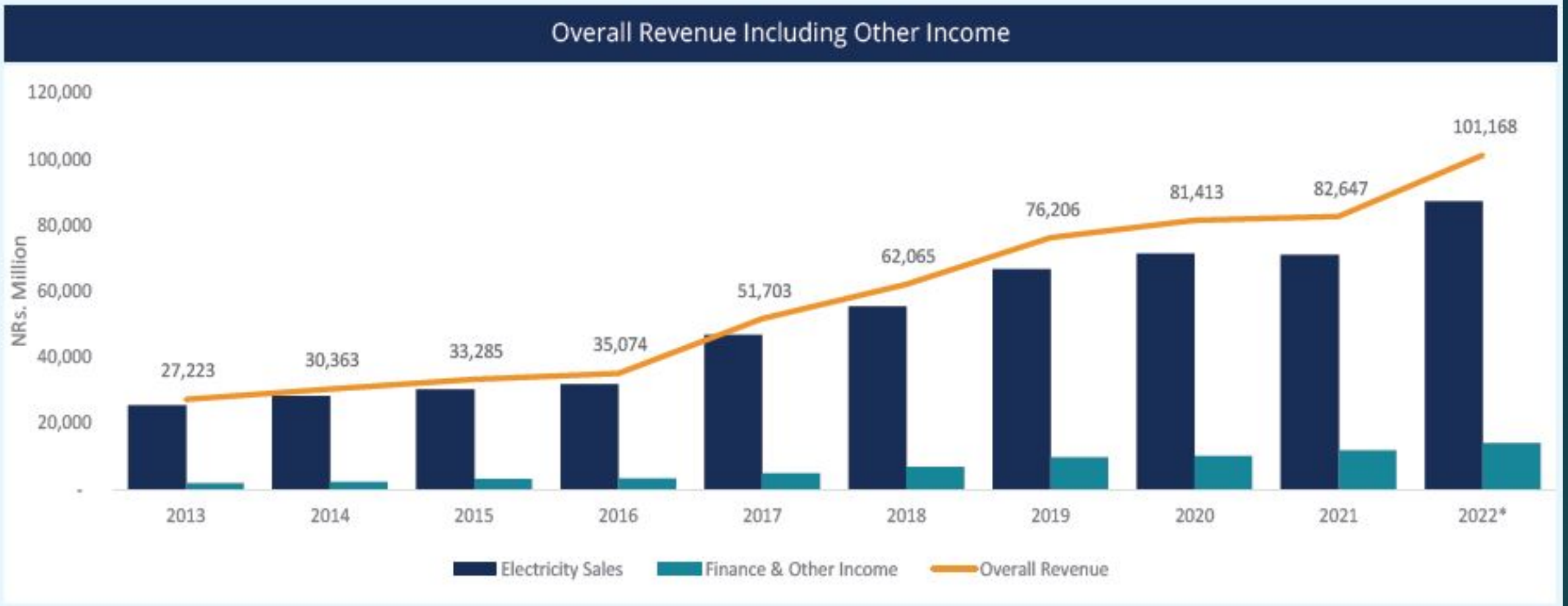
* Provisional Figures (Subject to Final Audit)

Imported Energy from different lines in FY 2077/78 (2020/21) and FY 2078/79 (2021/22)



Comparision of Exported Energy(Gwh) to India in different FY.




Overall Revenue Including Other Income
120,000
100,000
80,000
60,000
40,000
20,000
-
NRs. Million
27,223
30,363
33,285
35,074
51,703
62,065
76,206
81,413
82,647
101,168
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022*
Electricity Sales
Finance & Other Income
Overall Revenue

TOD (Time of Day) Tariff Rate

Consumer Category	Demand Charge Nrs./ KVA/ month	Peak Time (17.00-23.00)	Off Peak Time (23.00-5.00)	Normal time (5.00-17.00)
A. High Voltage				
1. Industrial (132 kV)	230.00	10.00	4.65	8.20
2. Industrial (66 kV)	240.00	10.10	4.75	8.30
B. Medium Voltage (33 KV)				
1. Industrial	250.00	10.20	5.25	8.40
2. Commercial	315.00	12.30	6.75	10.80
3. Non-Commercial	240.00	13.20	7.00	12.00
4. Irrigation	-	6.30	2.00	3.00
5. Water Supply				
a) Community Water Supply	-	6.20	3.10	4.60
b) Other Water Supply	150.00	10.20	5.25	8.40
6. Transportation				
a) Public Transportation (Charging Station)	230.00	7.00	3.70	5.50
b) Other Transportation	255.00	9.35	3.70	8.40
7. Street Light	80.00	8.40	3.50	4.20
C. Medium Voltage (11 KV)				
1. Industrial	250.00	10.50	5.40	8.55
2. Commercial	315.00	12.60	6.90	11.10

3.3.1 Public Transportation (Charging Station)

Description	Energy Charge Nrs./kWh		
	Peak Time (17.00-23.00)	Off Peak Time (23.00-5.00)	Normal Time (5.00-17.00)
Tariff Rate from Baisakh to Mangsir			
Medium Voltage (33 kV)	8.40	4.45	6.60
Medium Voltage (11 kV)	8.60	5.05	6.70
Low Voltage (230/400 V)	8.70	5.05	6.90
Tariff Rate from Paush to Chaitra			
Description	**Peak Time (17.00-23.00)**	**Normal Time (23.00-17.00)**	
Medium Voltage (33 kV)	8.40	6.60	
Medium Voltage (11 kV)	8.60	6.70	
Low Voltage (230/400 V)	8.70	6.90	

3.3.2 Other Transportation

Description	Energy Charge Nrs./kWh		
	Peak Time (17.00-23.00)	Off Peak Time (23.00-5.00)	Normal Time (5.00-17.00)
Tariff Rate from Baisakh to Mangsir			
Medium Voltage (33 kV)	11.20	4.45	10.10
Medium Voltage (11 kV)	11.60	5.05	10.20
Low Voltage (230/400 V)	11.70	5.15	10.30

Any Question?

THANK YOU